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S P E C I F I C A T I O N

Title of the Invention

Virtual Interfaces with Dynamic Binding

Background of the Invention

1. *Field of the Invention*

This invention relates to virtual interfaces with dynamic binding in a computer network environment.

2. *Description of Related Art*

In a computer network environment, it is often desirable to couple a local area network to a device remote from that local area network. When the local area network uses a protocol such as ethernet or token ring, devices to be coupled to the local area network generally require a network interface card or a similar device to establish connectivity. However, for a device remote from the local area network, a communication link to the

1 locality of the local area network, such as a serial link, is
2 generally required to establish connectivity. Providing connec-
3 tivity between a local area network and a remote is a problem
4 which has arisen in the art.

5
6 For example, it is often desirable to couple a local
7 area network to a router for connection to a second network. In
8 this manner, the local area network can achieve connectivity with
9 a network of networks (an internetwork) using the router. How-
10 ever, when the router is physically remote from the local area
11 network, connectivity between the router and the local area net-
12 work generally requires a communication link, such as a serial
13 communication link, which complicates the connection between the
14 router and the local area network.

15
16 One method in the art is to provide connectivity be-
17 tween the router and the local area network using a higher-level
18 protocol, such as the TCP/IP protocol. Devices coupled to the
19 local area network would then be able to communicate with net-
20 works coupled to the router, using the TCP/IP protocol or appli-
21 cations founded thereon. However, while this method provides
22 connectivity between the router and the local area network, it
23 requires additional complexity and additional processing for such
24 accesses, and does not truly allow routing packets over the se-
25 rial connection as if it were a local area network connection.
26 This additional complexity and failure to truly emulate a local
27 area network connection may also degrade or disable the use at
28 the router of applications designed for local area networks, even
29 though the router is thereby coupled to the local area network.

1
2 In addition to connectivity, it is often desirable to
3 couple a local area network to a remote location so as to provide
4 services to the local area network from that remote location.
5 For example, it may be advantageous to centralize administrative
6 services for a plurality of local area networks which are remote
7 from each other. However, the additional complexity of using a
8 higher-level protocol introduces additional complexity and incon-
9 venience to provision of those administrative services to the lo-
10 cal area network.

11
12 More generally, it is often desirable to substitute a
13 different type of physical device interface while maintaining the
14 same type of logical connectivity. For example, portable laptop
15 or notebook computers often provide a PCMCIA or "smart card" in-
16 terface, to which one of several types of devices may be coupled.
17 Some of these PCMCIA cards provide connectivity to a local area
18 network, but may require a special software controller for the
19 PCMCIA-based network interface. It would be advantageous to pro-
20 vide a method and system in which a software controller for the
21 network interface could operate independent of which type of
22 PCMCIA card is used to provide physical connectivity.

23
24 Accordingly, it is an object of the invention to pro-
25 vide improved connectivity to networks.
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Summary of the Invention

The invention provides a method and system for providing a virtual interface between a router and a network, in which the router is not connected to the network using a local interface. The invention also provides a method and system in which a router may be dynamically decoupled from a first network and coupled to a second network, without losing state information associated with the coupling to either network. In a preferred embodiment, the router comprises a virtual interface to the network, at which state information for the physical interface to the network is recorded, and a binding between the virtual interface and a physical interface, the latter of which is coupled to the network. In a preferred embodiment, dynamic binding of the virtual interface to the physical interface comprises an authentication step.

In a second aspect, the invention provides a method and system in which a router can be dynamically coupled to one of a plurality of local networks of differing types, such as one local network using an ethernet technique and one local network using a token ring technique. In this second aspect, the router comprises one virtual interface for each local network interface, a physical interface comprising a PC Card (PCMCIA card) controller, and one PC Card (PCMCIA card) network interface.

In a third aspect, a router is dynamically coupled to and decoupled from a set of networks sequentially, so that an administrator or an administrative program at the router may issue

1 administrative and/or set-up commands to each of the networks.
2 In a preferred embodiment, the administrative commands comprise
3 configuration commands, so that an administrator may configure a
4 plurality of networks from a single source location.

6 Brief Description of the Drawings

8 Figure 1 shows a block diagram of a computer network
9 environment including a router and a distant network.

11 Figure 2 shows a flow diagram of a method of communica-
12 tion between a router to a distant network, and data structures
13 used therewith.

15 Description of the Preferred Embodiment

17 In the following description, a preferred embodiment of
18 the invention is described with regard to preferred process steps
19 and data structures. However, those skilled in the art would
20 recognize, after perusal of this application, that embodiments of
21 the invention may be implemented using a set of general purpose
22 computers operating under program control, and that modification
23 of a set of general purpose computers to implement the process
24 steps and data structures described herein would not require in-
25 vention or undue experimentation.

GENERAL FEATURES OF THE METHOD AND SYSTEM

Figure 1 shows a block diagram of a computer network environment including a router and a distant network.

In a computer network environment 100, a network 101 comprises a communication medium 102 and at least one device 103 coupled thereto, using a network interface 104. (Typically, more than one device 103 is coupled to the network 101.) The network 101 may comprise a local area network ("LAN"), a wide area network ("WAN"), an internetwork, or a hybrid thereof. Local area networks, wide area networks and internetworks are known in the art of computer networking. For example, in preferred embodiments the network 101 may comprise either an ethernet LAN operating according to an ethernet protocol or a token ring LAN operating according to a token ring network protocol. Ethernet LANs, their communication media and network interfaces, as well as token ring LANs, their communication media and network interfaces, are known in the art of computer networking.

The Network Extender

The network 101 comprises a network extender 110 coupled to the communication medium 102 using a network interface 104. The network extender 110 comprises a special purpose processor or a general purpose processor operating under control of a program memory, and a data storage memory, and is disposed for connectivity to the network 101 using the network interface 104.

1 In a preferred embodiment, the network extender 110
2 comprises one of the "C1000 LAN Extender" products, available
3 from cisco Systems, Inc., of San Jose, California, and is dis-
4 posed to be configured for connectivity to an ethernet LAN or a
5 token ring LAN.

6
7 The network extender 110 is also coupled to a serial
8 port 111, and is disposed for controlling the serial port 111 ac-
9 cording to a known serial port protocol, preferably a point-to-
10 point protocol like that described with figure 2. The serial
11 port 111 is disposed for coupling to a serial communication link
12 112, such as a telephone line coupled to a telephone network 113
13 or other network.

14
15 In a preferred embodiment, the serial port 111 is dis-
16 posed to make a serial connection using the serial communication
17 link 112 by either making a call on the telephone network 113 or
18 receiving a call on the telephone network 113, using a telephone
19 line modem or other technique for transmitting digital informa-
20 tion using a telephone network. Serial communication using a
21 telephone network is known in the art of computer communication.

22 23 The Router

24
25 A router 120, remote from the network 101, comprises a
26 special purpose processor or a general purpose processor operat-
27 ing under control of a program memory, and a data storage memory.
28 As used herein, the term "remote" refers to logical remoteness,
29 and does not necessarily imply physical distance or another type

1 of remoteness. Similarly, as used herein, the term "local" re-
2 fers to logical locality, and does not necessarily imply physical
3 closeness or another type of locality.

4
5 In a preferred embodiment, the router 120 comprises any
6 cisco router product, available from cisco Systems, Inc., of San
7 Jose, California.

8
9 The router 120 comprises a serial port 121, and is dis-
10 posed for controlling the serial port 121 according to a known
11 serial port protocol, preferably a point-to-point protocol like
12 that described with figure 2. The serial port 121 is disposed
13 for coupling to a serial communication link 122, such as a tele-
14 phone line coupled to the same telephone network 113 or other
15 network, similar to the serial port 111 and the serial communica-
16 tion link 112.

17
18 In a preferred embodiment, the serial port 121 is dis-
19 posed to make a serial connection using the serial communication
20 link 122 by either making a call on the telephone network 113 or
21 receiving a call on the telephone network 113, using a telephone
22 line modem or other technique for transmitting digital informa-
23 tion using a telephone network, similar to the serial port 111
24 and the serial communication link 112.

25
26 The serial link 112 and the serial link 122 may be cou-
27 pled to form a communication link 123, such as using a telephone
28 virtual circuit on the network 113, so that serial communication
29 between the two is possible.

1
2 In a preferred embodiment, the router 120 is coupled to
3 one or more second networks 124, each of which may comprise a lo-
4 cal area network, a wide area network ("WAN"), an internetwork,
5 or a hybrid thereof. In preferred embodiments the second network
6 124 may comprise either a local area network or an internetwork,
7 and the router 120 may be disposed for bridging, brouting, gate-
8 waying or routing packets between the first network 101 and the
9 second network 124. Bridging, brouting (i.e., operating as a
10 brouter), gatewaying (i.e., operating as a gateway) and routing
11 are known in the art of computer networking.

12 13 The Interface Controller

14 The router 120 comprises an interface controller 130
15 coupled to the serial port 121. In a preferred embodiment where
16 the router 120 is a general purpose processor operating under
17 software control, the interface controller 130 comprises device
18 control software in the router's program memory and operates un-
19 der the control of operating system software in the router's pro-
20 gram memory. The interface controller 130 is disposed to control
21 the serial port 121 and to couple the serial port 121 to an ap-
22 plication 131 operating with the router 120. (The application
23 131 preferably implements a point-to-point protocol like that de-
24 scribed with figure 2.) Coupling application software to a de-
25 vice under control of device control software is known in the art
26 of computer operating systems.
27
28
29

1 The interface controller 130 comprises a physical con-
2 troller 132, which is disposed for controlling the serial port
3 121, i.e., to receive status signals from the serial port 121, to
4 transmit configuration signals to the serial port 121, and to
5 transceive data signals between the serial port 121 and an emu-
6 lated port 133.

7
8 In a preferred embodiment, the emulated port 133 is a
9 software object comprising a set of methods which the physical
10 controller 132 exports and which the virtual controller 134 in-
11 herits for construction of its virtual port 135. Software ob-
12 jects having exportable and inheritable methods are known in the
13 art of computer programming.

14
15 The emulated port 133 is disposed for coupling, by the
16 router's operating system software, to a virtual controller 134.
17 The virtual controller 134 is disposed to couple the application
18 131 to the emulated port 133, i.e., to receive configuration sig-
19 nals from the application 131, to transmit status signals from
20 the physical controller 132 at the emulated port 133, and to
21 transceive data signals between the emulated port 133 and a vir-
22 tual port 135.

23
24 The virtual port 135 provides the application 131 with
25 the same interface as if the router 120 were coupled directly to
26 the network 101 using a directly connected network interface 104.
27 Accordingly, there is one type of virtual controller 134 for each
28 type of network interface 104 to which the router 120 is disposed
29 for coupling. In a preferred embodiment, the virtual controller

1 134 is configured for ethernet LANs operating according to an
2 ethernet protocol. When a communication link 123 is established
3 between a network extender 110 and the router 120, the router's
4 operating system selects the virtual controller 134 matching the
5 network extender 110 and its network 101 for coupling to the
6 physical controller 132.

7 8 Dynamic Binding

9
10 In a preferred embodiment, the serial port 121 is dis-
11 posed for dynamic binding to one of a plurality of serial ports
12 111, by sequentially making and breaking the communication link
13 123 between the router 120 and one of a plurality of network ex-
14 tenders 110. The plurality of network extenders 110 are prefera-
15 bly each coupled to a different network 101, so dynamic binding
16 of the serial port 121 allows the router 120 to sequentially cou-
17 ple to one of a plurality of networks 101.

18
19 In a preferred embodiment, an operator sets up an ini-
20 tial configuration for the virtual controller 134, indicating
21 which virtual controller 134 should be bound to which network ex-
22 tender 110, preferably matching the MAC address of the network
23 extender 110 to the initial configuration for the virtual con-
24 troller 134, such as an initial configuration for an ethernet LAN
25 operating using an ethernet LAN protocol. The router's operating
26 system creates one software instantiation of the virtual control-
27 ler 134 for each matching network extender 110 to be coupled to
28 the router 120. This allows each software instantiation of the
29 virtual controller 134 to dispense with switching context when

1 the communication link 123 is made or broken. Multiple software
2 instantiations are known in the art of computer operating sys-
3 tems.

4
5 Each instantiation of the virtual controller 134 also
6 maintains state information about the emulated port 133 and the
7 first network 101, in a status record 136, as if the communica-
8 tion link 123 between the network extender's serial port 111 and
9 the router's serial port 121 were continually coupled. Informa-
10 tion in the status record 136 is maintained persistently across
11 multiple sessions of the communication link 123. This informa-
12 tion includes authentication/identification data 137 for the com-
13 munication link 123, such as a unique identifier for the network
14 extender 110. In a preferred embodiment, the authentica-
15 tion/identification data 137 comprises the MAC address for the
16 device embodying the network extender 110 and is received from
17 the network extender 110 when the communication link 123 is es-
18 tablished.

19
20 In alternative embodiments, the authentica-
21 tion/identification data 137 may comprise different or additional
22 information. For example, the authentication/identification data
23 137 may comprise an identifying serial number for the network ex-
24 tender 110. The authentication/identification data 137 may also
25 comprise information for a more elaborate or secure method of
26 authentication, such as a password.

27
28 The physical controller 132 is re-usable and rebindable
29 to a new virtual controller 134 each time the communication link

1 123 is made or broken. In alternative embodiments, the physical
2 controller 132 may also comprise a controller for a multichannel
3 interface, i.e., a physical interface which abstracts a plurality
4 of communication links 123, such as a communication link with a
5 plurality of channels, separated by frequency division, time di-
6 vision, or another technique.

7 8 Network Administration

9
10 In a preferred embodiment, the application 131 is dis-
11 posed to supply administrative services to the network 101 when
12 the router 120 is coupled to the network extender 110. The ap-
13 plication 131 supplies administrative control packets 140 to the
14 virtual controller 134, which couples them to the emulated port
15 133 and the physical controller 132, which couples them to the
16 serial port 121 and the serial link 122, which couples them using
17 the communication link 123 to the serial link 112 and the serial
18 port 111 at the network extender 110, which couples them to the
19 network 101, all using a point-to-point protocol described with
20 figure 2. On the network 101, the network extender 110 receives
21 the administrative control packet 140 and processes it accord-
22 ingly to effect a network administrative service.

23 24 Alternative Interface Devices

25 In alternative embodiments, a physical controller 132
26 may be disposed to control a physical interface different from
27 the serial port 121. For example, in an alternative preferred
28 embodiment, a PCMCIA port 121 is substituted for the serial port
29

1 121, and a physical controller 132 tailored to the PCMCIA port
2 121 is substituted for the physical controller 132 tailored to
3 the serial port 121. The PCMCIA port 121 is disposed for being
4 coupled to a PCMCIA card 150; the PCMCIA card 150 may comprise a
5 network interface 104 for a network 101, or another device such
6 as a flash memory, a hard disk drive, a modem, or a radio trans-
7 ceiver.

8
9 The virtual controller 134 may be coupled to the physi-
10 cal controller 132 for the PCMCIA port 121 while the PCMCIA port
11 121 is coupled to a PCMCIA card 150, so that the application 131
12 may be coupled to the PCMCIA card 150 using the interface pro-
13 vided by the virtual port 135.

14
15 In general, the physical controller 132 may comprise
16 any form of connection between the router 120 and the network ex-
17 tender 110, or more generally, any form of connection between two
18 devices, such as a serial port and a serial port controller, a
19 PCMCIA port and a PCMCIA port controller, a computer backplane,
20 or another form of connection. The virtual controller 134 may
21 comprise any interface to the physical controller 132, such as an
22 ethernet interface, a token ring interface, a PCMCIA interface,
23 or another form of interface, and need not be constrained by the
24 physical nature of the connection.

COMMUNICATION BETWEEN THE ROUTER AND THE NETWORK

Figure 2 shows a flow diagram of a method of communication between a router to a distant network, and data structures used therewith.

At a flow point 250, the application 131 desires to send a network packet 200 onto the network 101.

At a step 251, the router 120 builds the network packet 200, comprising a packet header 201 and a packet body 202. The packet header 201 comprises a destination address for a device 103 on the network 101; the packet body 202 comprises a sequence of data intended for the destination addressee device 103.

In a preferred embodiment, the network packet 200 comprises either an ethernet LAN packet, constructed according to an ethernet LAN protocol, or a token ring LAN packet, constructed according to a token ring LAN protocol. Both ethernet LAN protocols and token ring LAN protocols are known in the art.

At a step 252, the router 120 wraps the packet 200 in a LEX protocol wrapper 210, comprising a LEX header 211 and a LEX body 212. The LEX protocol is the protocol used by the router 120 for communication with the network extender 110 using the communication link 123. The LEX body 212 comprises either a sequence of data for the network extender 110 to redistribute onto the network 101 (that is, a network packet 200), or may comprise a control message designated for the network extender 110 itself.

1
2 At a step 253, the router 120 transmits the LEX proto-
3 col wrapper 210 to the network extender 110 using the communica-
4 tion link 123.

5
6 At a step 254, the network extender 110 receives the
7 LEX protocol wrapper 210 using the communication link 123. The
8 network extender 110 detects the LEX header 211 and separates the
9 LEX header 211 from the LEX body 212.

10
11 At a step 255, the network extender 110 interprets the
12 LEX header 211, which designates the LEX body 212 as intended for
13 redistribution onto the network 101 (that is, a network packet
14 200), or as intended as a control message designated for the net-
15 work extender 110 itself. If the LEX body 212 is a network
16 packet 200, the network extender 110 proceeds to the step 256.
17 Otherwise, the network extender 110 proceeds to the step 257.

18
19 At a step 256, the network extender 110 unwraps the LEX
20 header 211 from the LEX protocol wrapper 210, and redistributes
21 the LEX body 212 as a network packet 200 onto the network 101 us-
22 ing the network interface 104. The network's communication me-
23 dium 102 transmits the network packet 200 to its destination de-
24 vice 103 (or devices 103, for example if the network packet 200
25 is a broadcast packet).

26
27 At a step 257, the network extender 110 unwraps the LEX
28 header 211 from the LEX protocol wrapper 210, and interprets the
29 LEX body 212 as a control message.

1
2 The following set of control messages comprises a set
3 for a network extender 110 coupled to an ethernet LAN and operat-
4 ing according to an ethernet LAN protocol. In alternative em-
5 bodiments, or with alternative network extenders 110 coupled to
6 alternative networks 101, there might be a different set of con-
7 trol messages, or no control messages. For example, when the
8 physical controller 132 is coupled to a PCMCIA card 150, there
9 might be no control messages implemented at all.

10
11 A first control message comprises a negotiation control
12 message for directing the network extender 110 to negotiate a set
13 of parameters for establishing the communication link 123. The
14 negotiation control message comprises a protocol version value,
15 indicating the version of the LEX protocol supported by the
16 router 120. The network extender 110 receives the protocol ver-
17 sion value and responds with a negotiation control message indi-
18 cating the version of the LEX protocol it supports. The router
19 120 and the network extender 110 each adjust their treatment of
20 the communication link 123 to use the lower-numbered version of
21 the LEX protocol.

22
23 A second control message comprises a protocol filtering
24 control message for directing the network extender 110 to filter
25 network packets 200 for those packets it should forward to the
26 router 120 and those packets it should not forward. The protocol
27 filtering control message comprises a sequence of tuples 213, in
28 a canonical order, each tuple 213 comprising a protocol type 214
29 and a permit/deny bit 215 indicating whether a network packet 200

1 having that protocol type 214 should be forwarded or discarded.
2 The sequence of tuples 213 is preceded by a sequence length
3 field; a zero length sequence of tuples 213 is interpreted by the
4 network extender 110 as a command to turn protocol filtering off.

5
6 A third control message comprises a destination filter-
7 ing control message for directing the network extender 110 to
8 filter network packets 200, similar to the protocol filtering
9 control message. The destination filtering control message com-
10 prises a sequence of tuples 213, in a canonical order, each tuple
11 213 comprising a destination address 216 and a permit/deny bit
12 215 indicating whether a network packet 200 having that protocol
13 type 214 should be forwarded or discarded. The sequence of tu-
14 ples 213 is preceded by a sequence length field; a zero length
15 sequence of tuples 213 is interpreted by the network extender 110
16 as a command to turn destination filtering off.

17
18 The network extender 110 parses the filtering control
19 message and the destination filtering control message, and in re-
20 sponse constructs a trie 217 embodying the instructions in the
21 sequence of tuples 213 of protocol types 214 and permit/deny bits
22 215 or tuples 213 of destination addresses 216 and permit/deny
23 bits 215. When the network extender 110 receives a network
24 packet 200, as at the step 262, it matches the protocol type 215
25 and destination address 216 of the network packet 200 against the
26 trie 217 to determine whether it should forward or discard the
27 network packet 200.

1 In a preferred embodiment, the router 120 already com-
2 prises means for filtering packets 200 for those packets 200 it
3 should forward to the network 101 and those packets 200 it should
4 not forward, and does not generally require filtering information
5 from the network extender 110.

6
7 A fourth control message comprises a priority queuing
8 control message for directing the network extender 110 to priori-
9 tizing packets 200 to be queued for transmission to the router
10 120 using the communication link 123. The priority queuing con-
11 trol message comprises a sequence of tuples 213, in a canonical
12 order, each tuple 213 comprising a protocol type 214 and a priori-
13 ty value 218 indicating what priority value to assign a network
14 packet 200 having that protocol type 214. The sequence of tuples
15 213 is preceded by a sequence length field; a zero length se-
16 quence of tuples 213 is interpreted by the network extender 110
17 as a command to assign all packets the same priority value.

18
19 A fifth control message comprises a report statistics
20 control message for directing the network extender 110 to respond
21 with a report of operational statistics. The report statistics
22 control message comprises a set of statistics flags, directing
23 which statistics to report and directing the network extender 110
24 whether to reset those statistics upon reporting them.

25
26 In a preferred embodiment, the statistics flags com-
27 prise a first flag directing the network extender 110 to resent
28 statistics after reporting, a second flag directing the network
29 extender 110 to report statistics regarding the communication

1 link 123, and a third flag directing the network extender 110 to
2 report statistics regarding the network's communication medium
3 102. Statistics to be reported may comprise numbers of packets
4 transmitted or received, errors of various types, latency times,
5 transmission rates for packets or data, and other statistics
6 known in the art of computer networking.

7
8 A sixth control message comprises a reboot control mes-
9 sage for directing the network extender 110 to reboot itself.

10
11 A seventh control message comprises a download control
12 message for directing the network extender 110 to download data
13 comprising a program, a set of options, or other data.

14
15 An eighth control message comprises a download status
16 control message for directing the network extender 110 to report
17 status of a recent download control message.

18
19 A ninth control message comprises a disable network
20 control message for directing the network extender 110 to disable
21 its connectivity to the network 101.

22
23 A tenth control message comprises an enable network
24 control message for directing the network extender 110 to enable
25 its connectivity to the network 101.

26
27 An eleventh control message comprises an inventory con-
28 trol message for directing the network extender 110 to respond
29

1 with a report of its hardware and software, including version
2 numbers.

3
4 At a flow point 260, a device 103 on the network 101
5 desires to send a packet 200 to the router 120 (or to a destina-
6 tion device coupled to the router's second network 124).

7
8 At a step 261, the device 103 builds the network packet
9 200, comprising a packet header 201 and a packet body 202, and
10 sends the network packet 200 on the network's communication me-
11 dium 102. The packet header 201 comprises a destination address
12 for the device 103 on the router's second network 124; the packet
13 body 202 comprises a sequence of data intended for the destina-
14 tion addressee device 103.

15
16 At a step 262, the network extender 110 receives the
17 network packet 200-using the network's communication medium 102.
18 The network extender 110 detects the packet header 201 and deter-
19 mines whether the destination address is one it should forward to
20 the router 120. If the destination address is one it should for-
21 ward, the network extender 110 proceeds to the step 263. Other-
22 wise, the network extender 110 discards the packet 200.

23
24 At a step 263, the network extender 110 attempt to make
25 a communication link 123 with the router 120. If the network ex-
26 tender 110 already has a communication link 123 is progress with
27 the router 120, the network extender 110 proceeds to the step
28 264. Otherwise, the network extender 110 establishes the commu-
29 nication link 123 with the router 120 using the telephone network

1 113. Establishing communication links using a telephone network.
2 is known in the art of computer communication.

3
4 At a step 264, the router 120 receives the incoming
5 communication link 123 to the router's serial port 121. The
6 router 120 negotiates with the network extender 110 to establish
7 the communication link 123 with acceptable parameters (for exam-
8 ple, line speed), using a negotiation control message described
9 with the step 257. Negotiation to establish link parameters is
10 known in the art of computer communication.

11
12 At a step 265, the network extender 110 transmits
13 authentication information to the router 120 using the communica-
14 tion link 123. In a preferred embodiment, the authentication in-
15 formation is a MAC address for the network extender 110.

16
17 At a step 266, the router 120 receives the authentica-
18 tion/identification information and attempts to authenticate the
19 network extender 110. If the router 120 is able to authenticate
20 the network extender 110, it proceeds to the step 267. Other-
21 wise, the router 120 so informs the network extender 110 and
22 breaks the communication link 123.

23
24 In alternative embodiments, the step 265 and the step
25 266 may comprise a more elaborate or secure method of identifica-
26 tion and authentication, such as PPP CHAP. For example, the step
27 266 may comprise a distinct authentication technique, and may
28 comprise the exchange of information between the network extender
29 110 and the router 120 using the communication link 123. In such

1 alternative embodiments, the router 120 attempts to identify and
2 authenticate the network extender 110 before binding the virtual
3 controller to the physical controller for the communication link
4 123 in the step 267.

5
6 At a step 267, the router 120 searches a lookup table
7 for the virtual controller 134 associated with the network ex-
8 tender 110, and binds that virtual controller 134 to the physical
9 controller 132 for the communication link 123. In a preferred
10 embodiment, the MAC address for the network extender is associ-
11 ated with a single virtual controller 134. If no such virtual
12 controller 134 exists (that is, the type of virtual port 135 is
13 known but there is no instantiation of the virtual controller 134
14 for this particular network extender 110), the router 120 creates
15 an instantiation of the associated virtual controller 134 and as-
16 signs that virtual controller 134 parameters for the communica-
17 tion link 123.

18
19 At a step 268, the network extender 110 wraps the net-
20 work packet 200 in the LEX protocol wrapper 210, comprising a LEX
21 header 211 and a LEX body 212, and transmits the LEX protocol
22 wrapper 210 to the router 120 using the communication link 123.
23 The LEX body 212 comprises the network packet 200.

24
25 At a step 269, the router 120 unwraps the LEX header
26 211 from the LEX protocol wrapper 210. The router 120 compares
27 the LEX body 212 against an access list or a filter list to de-
28 termine if the LEX body 212 should be forwarded to the second
29 network 124. If so, the router 120 redistributes the LEX body

1 212 as a network packet 200 onto the second network 124, and the
2 second network 124 transmits the network packet 200 to its desti-
3 nation device 103 (or devices 103, for example if the network
4 packet 200 is a broadcast packet). Otherwise, the router 120
5 discards the LEX body 212.

6
7 The network extender 110 is also disposed to send a LEX
8 protocol wrapper 210 comprising a LEX header 211 and a LEX body
9 212, where the LEX body 212 is a control message to the router
10 120 or a response to a control message from the router 120. When
11 the LEX body 212 is a control message or a response to a control
12 message, the router 120 detects this and does not forward the LEX
13 body 212 onto the second network 124.

14 15 **Alternative Embodiments**

16
17 Although preferred embodiments are disclosed herein,
18 many variations are possible which remain within the concept,
19 scope, and spirit of the invention, and these variations would
20 become clear to those skilled in the art after perusal of this
21 application.